International Journal of Disaster Risk Reduction 31 (2018) 691–697

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

An analysis of the flood management and mitigation measures in Zimbabwe for a sustainable future

Remember Samu*, Aysu Sagun Kentel

Sustainable Environment and Energy Systems, Middle East Technical University, Northern Cyprus Campus, Mersin 10, Kalkanli, Guzelyurt, Turkey

ARTICLE INFO

Keywords:
Flood protection
Flood risk management
Precipitation
Sustainable flood management
Zimbabwe

ABSTRACT

Floods have prevailed in the recent years, hampering not only social but also the economic development as well. This global pandemic has caused loss of lives, property and economic damages in many countries, including Zimbabwe. Rainfall intensity in the country's seven main river catchments namely; Mzingwane, Gwayi, Save (or Sabi), Mazowe (or Mazoe), Sanyati, Manyame and Runde triggers flash floods due to high peak discharges. It is therefore of paramount importance to try and reduce or rather prevent these losses due to flood events. The main objective of this study is to ascertain flood events in Zimbabwe and discuss how best they can be managed for a sustainable future. The assessment is carried out using AQUEDUCT Global Flood Analyzer in which all the analysis is based on the Gross Domestic Product (GDP), population and the present and future (2030) urban damage. To estimate future changes and effectively suggest flood disaster management and mitigation strategies, three scenarios obtained from the Intergovernmental Panel on Climate Change 5th Assessment Report were utilized. A 5-year flood protection was then employed and the urban damage due to the flood events, the population at risk and the effects of this disaster on GDP was determined. This study outlined that in any given year, the majority of Zimbabwe has a low to a medium that is 2–3% probability of flood occurrence in which a 5-year flood has a 20% occurrence probability in any given year. If there is no flood protection employed, this 5-year flood could cause $106.3 thousand affected population, $32.4 million urban damage and $67.9 million affected GDP. It is concluded that it is impossible to completely eliminate flood events, however, proposed mitigation measures, diminution approach and proper planning and preparation before their occurrence can reduce the environmental, economic and social losses.

1. Introduction

Natural disasters in the form of floods, droughts, tornadoes, hurricanes, tsunamis, among others have frequently prevailed due to climate change all around the world. Extreme cases of these disasters have resulted in intense damages to property and loss of lives. One of the greatest impacts of climate change that has been recorded is flooding, which is a result of the release of enormous volumes of water unexpectedly from storage, for example from dams, snow packs or tidal influences or is mostly caused by extreme precipitation [16].

Flooding can be defined as an overflow of a large amount of water beyond its normal limits, especially over what is normally dry land displacing people by demolishing their assets, houses, other substantial goods and land [26]. Increase in the losses due to flooding over the years are highly influenced by high rates of urbanization of the flood-prone areas, a lot of sub-customary constructions, amendments of the usage of land, an increase in population densities and mainly due to global warming. Land use, in particular management, urban planning and the design of flood defence structures highly influence the damages caused or avoided by flooding [19]. Due to these and many more reasons, chances of flooding in cities are high mainly due to high population densities and because of how economic activities are concentrated [5].

Reported statistics revealed that yearly, floods claim 250 people lives in Zimbabwe (Farai [14]). Flooding also causes severe impacts resulting in a disruption in transport, communication, consequential impacts on the environment, interference with the public services, deterioration of quality and quantity of water and major effect on energy. One of the most important communities affected by flooding is school children especially in the rural areas of Zimbabwe. As outlined by [8], not only does flooding result in loss of learning hours or outbreak of waterborne diseases, but the extremes might indirectly lead to early marriages thus compromising children's rights. The long-term effects will include but not limited to an increase in food prices and migration.

* Corresponding author.
E-mail address: samu.remember@metu.edu.tr (R. Samu).

https://doi.org/10.1016/j.ijdrr.2018.07.013
Received 15 March 2018; Received in revised form 18 July 2018; Accepted 18 July 2018
Available online 20 July 2018
2212-4209/ © 2018 Elsevier Ltd. All rights reserved.

Mitigation of flood events is therefore of paramount importance not only in the social lives but also since the costs of the disaster continue to rise. A cost-benefit analysis of the reduction of disaster risk has an economic benefit as well [30].

The main objective of this study is to analyze the probable causes of flooding in Zimbabwe and explore possible as well as sustainable mitigation measures to reduce or better eliminate the impacts for a sustainable future. Future flood events are predicted up to the year 2030 as well. This was done to predict the losses that could be suffered given different scenarios so as to determine how best the losses due to these future flooding events could be reduced. Within this context, three different scenarios were analysed where 5-year flood protection level was employed and the rate of urban damage, affected Gross Domestic Product (GDP) and the affected population in Zimbabwe were determined.

2. Background

The intense concentration of the economic activities, as well as rapid increases in the population densities, have increased chances of inland flooding in cities. There have been some cause and impact analysis studies of floods for different regions. A study was conducted prior to the flood that occurred on 3 June 2015 in Accra, the capital city of Ghana. It was a devastating disaster in which more than 152 lives were lost and some worthy properties were destroyed [4]. A 10-year flood protection level model was employed to analyze avoided urban damage.

Asumadu-Sarkodie et al. [5], made an analysis of drought and flood in Rwanda. They also utilized AQUEDUCT Global Flood Analyzer. In their report, they concluded that Rwanda has more than 20% probability of inland flooding in any given year and a 10-year flood could cause $6.1 million worth of urban damage and the probability of occurrence in any given year is 10% [5].

Utilizing precipitation data from the National Meteorological Information Center of China, studies of the causes and variations of flood and drought hazards in South China were conducted [17]. The results of the study reveal that some places in the southwest and north of Guangxi, Guangdong and the junction of Fujian and Jiangxi were at high risk of excess flooding. Results of the first modelling exercise to assess the link between inter-annual climate variability, duration and flood frequency show that flooding duration is more sensitive to El Niño Southern Oscillation (ENSO) than the case of the frequency of the flood [33].

All these studies show that flooding is a growing and serious sustainable development challenge. Against the backdrop of climate changes, urbanization trends and demographic growth, there has been a shift in the causes of floods and the rate of impacts is accelerating. The risk profiles of many African countries are shaped by their social structures, that is urbanization, city governance systems and economic pathways [9,29]. These evolving challenges, therefore, need improved and more sustainable methodologies as well as policies to manage both current and possible future risks (Abhas [1]).

3. Flood history and management in Zimbabwe

Zimbabwe is a landlocked country straddling the high plateau between the Zambezi river to the north and the Limpopo River to the south with a tropical climate. Water bodies constitute a total area of 6.8% of the total area of Zimbabwe. On average annually Zimbabwe receives a rainfall of 266,666 million m^3 and 7.5% of this is carried by rivers. The Zambezi and the Limpopo basins are the largest of the 6 basins making up the hydrography of Zimbabwe.

In the year 2000, on February 22, a tropical cyclone, Cyclone Eline hit Zimbabwe affecting the southern and eastern parts of the country. When this tropical cyclone came, the main river basins namely the Limpopo and the Save River basin were already facing a life-threatening flood. In this flood,106 lives being lost, and 500,000 people were affected.

Zimbabwe was also struck by floods during the period December 2010 to January 2011, where some areas recorded their heaviest rainfall in over 30 years. The country suffered from severe flooding in early January 2013, in particular, Matabeleland South, Matabeleland North, Manicaland, Mashonaland Central, Masvingo and Midlands. The floods affected around 10,000 people and caused widespread destruction of crops and farmland.

Masvingo province normally receives 450 mm (18″) of rainfall per annum, but in 2014 it exceeded 850 mm (33″), causing widespread flooding. The floods posed danger to people living in Ngundu, Gororo, Triangle and Nyahombe. More than 62,000 people were affected due to this flooding and it was declared a state of disaster. The floods were caused by huge volumes of water that have forced their way through the dam wall of Tokwe-Mukorsi Dam that was still under construction. Due to prevailing floods in Tokwe-Mukorsi community, a study conducted by [12] proved that households living downstream and upstream of the dam were vulnerable to floods due to the construction of Tokwe-Mukorsi Dam.

In the year 2015, at least 6 provinces in Zimbabwe, namely Masvingo, Midlands, Manicaland, Mashonaland East, Mashonaland West and Mashonaland Central were affected by floods. At least 10 people were reported dead, more than 200 houses were damaged and 200 families were displaced (Richard Davies, 2015). During the 2016 rainy season, the public was warned to be on high alert on flash floods as more than 394 homesteads and 13 schools were destroyed. In the same year, 200 miners at Hwange Colliery Company were trapped underground due to flooding with more than 31 fatalities were reported. In 2017 a river flood occurred and a total of 909 people were evacuated from Tsholotsho and Mberengwa districts and 1 bridge in Umzingwane district was destroyed.

As outlined above, these flood events have prevailed almost every year recently and this has motivated the authors to further present this study. 11 severe floods have been recorded in Zimbabwe from the year 1900–2016 causing a total affected population of 344,022 (EM-DAT, 2016).

Two types of flood management and mitigation measures are currently employed in Zimbabwe namely non-structural and structural measures. In structural mitigation type, dams and weirs are built to store the runoff water. Some of the major dams constructed for this purpose in the Zambesi river basin are Seke, Bhiri-Manyame, Harava, Bumururu, Karoi, Eastworlds, Manyame, Chivero, Blockley, Pembi, Mazvikadei and Kariba. The non-structural mitigation type comprises flood forecasting, evacuation, rescuing and resettlement of the victims. The Meteorological Service Department of Zimbabwe is the one responsible for forecasting. The evacuation or rescue operations in Zimbabwe are coordinated by the civil protection organization together with the Zimbabwe Red Cross and Red Crescent Society and some non-governmental organizations. Education is a major tool that is utilized in some parts of Zimbabwe as a flood management and mitigation strategy. A study by [10] proved that communities with a strong socio-economic base like education were more likely to cope with flood impacts compared to communities with a weak socio-economic base. Recently, the rate of floods has increased, for each water year. Against this backdrop, this present study deems necessary to outline some the causes of flooding in Zimbabwe and propose sustainable management and mitigation approaches for future generation.

4. Scenario-based case studies: flood risk assessment in Zimbabwe

Three scenarios (Scenario A, B and C) are conducted for the flood risk assessment in Zimbabwe, The details of each Scenario can be found in Section 5.1. The meteorological data are obtained using Meteonorm V7 software and Aqueduct Global Flood Analyzer software was utilized to determine the population affected by the flood events, the affected

GDP and the probability of flood occurrence.

4.1. Objectives

For a deeper analysis of losses due to disasters, data availability of the prevailing disasters is of paramount importance. However, the availability of robust data has been a major failure in many Sub-Saharan African countries [25]. One of the objectives of this present study is to determine the population affected by the flood events, the affected GDP and the probability of flood occurrence. GDP in this context is the monetary value of all the finished goods and services produced in Zimbabwe annually. In order to predict the changes in the future, three scenarios were designed and implemented as the Representative Concentration Pathways (RCP), IPCC Scenario A2 and the Shared Socio-economic Pathways (SSP). These scenarios will be explained in detail in Section 5.1 of this present paper. These implemented scenarios also support the facts that health, demographic characteristics and socioeconomic status are top empirical drivers of social vulnerability to flood events that are damaging [28]. Furthermore, some objectives to be covered in this present study are; reasons as to why some flood mitigation measures currently being employed in Zimbabwe have failed and other sustainable flood management and mitigation measures will be proposed.

4.2. Research methodology

In this study, the population affected by the flood events, the affected GDP and the probability of flood occurrence are determined by utilizing Aqueduct Global Flood Analyzer and employing a 5-year flood protection level. *Flood protection* level defines how best any given area is protected against a flood damage [2]. *Flood occurrence* refers to the total numerical amount of flood that occurred in the years 1985–2011 [3].

4.3. Research tools

In this study, Meteonorm V7 software was used to obtain the meteorological data. Meteonorm is a unique combination of reliable data sources and sophisticated calculation tools in which accurate meteorological data for any place on earth are generated [23]. In this research, data used for the determination of the current average monthly precipitation was from 1981 to 2010.

Studies considering the amount of rainfall have proved reliable in the determination of climate change variables since flooding is directly dependent on the amount of precipitation ([6,7], Edenhofer et al., 2012). Aqueduct Global Flood Analyzer was used for the flood risk analysis in Zimbabwe. This software assumes that population growth, climate change and global economic development will alter the competition for and availability of water around the world. Projections of climate variables were driven primarily by general circulation models from the Coupled Model Intercomparison Project (CMIP) Phase 5 project, and socioeconomic variables were based on the Shared Socioeconomic Pathways database from the International Institute for Applied Systems Analysis [18]. The CMIP is an experimental standardized framework employed for studying the output of coupled atmosphere-ocean general circulation models. Aqueduct flood analyzer has been employed in a few studies for flood hazard mapping as well as the determination of future flood risks [11,15,31,34]. A series of models such as the Grid-to-Grid hydrological model or 3-D non-hydrostatic models are employed for the estimation of river flooding impacts. These impacts are mainly focused on the amount of urban damage in (US dollars) caused by floods, the GDP that will be exposed to floods and the population that will be affected by floods.

Between the years 1985 and 2011, a couple of floods were recorded in the catchments and the Flood Occurrence (FO) was used to measure them. From this, the flood extent was reported and obtained from the Global Flood Observatory and remote sensing was used for the estimation [13]. This was modelled mathematically as in Eq. (1).

$$r_\mathrm{FO},\ _j = \mathrm{count}(\{E/E \cap \mathrm{j} \neq \varnothing\}) \quad (1)$$

where E is the polygons' extent that are joined spatially to the j catchments so as to count the floods which each catchment may affect the recorded time period. Eq. (2) is used for the calculation of the discharge of each basin [21,32].

$$\boldsymbol{Qp} = 0.278 \times Cs \times C \times i \times A \quad (2)$$

where $\boldsymbol{Qp}$ is the rate of run-off in m^3/s, Cs is the coefficient of storage, C is the coefficient of runoff, A is the drainage area in km^2 and i is the intensity of rainfall in mm/h. 0.75–0.95 is the range of the coefficient of runoff in urban areas.

4.4. Scenario definitions

In this study, the flood risk estimation by Aqueduct Global Flood Analyzer is based on the urban damage for current year and future (up to 2030), the country's increased population and the affected GDP. Changes in the future are predicted for their estimation, Shared Socioeconomic Pathways (SSP) and the Representative Concentration Pathways (RCP) scenarios were employed. Table 1 summarizes the employed scenarios and their descriptions.

5. Results

Aqueduct Water Risk Atlas was utilized for flood occurrence analysis and Fig. 1 shows the obtained results. There is a high probability (10–27%) of flooding in Midlands, Masvingo and eastern parts of Matabeleland provinces as well as the eastern border and the Zambesi regions of Zimbabwe. The majority has a 2–3% flood occurrence probability which falls in the low to medium scale.

The analysis was performed by utilizing Aqueduct global flood analyzer. A 5-year flood protection level was employed and the rate of urban damage, affected GDP and the affected population were determined. Possible monetary losses are deduced for both situations, in case of employment and lack of a flood protection level to point out the importance of a flood protection level and a predicted flood forecast up to 2030 is presented.

5.1. Urban damage in Zimbabwe

In this present study, Urban Damage refers to an annualized estimated amount of the assets damaged due to inland flooding. Based on a 5-year flood protection level, Fig. 2 shows the urban damage in Zimbabwe. Fig. 3 outlines the relationship between the probability of a flood occurrence and the flood event. In Fig. 2, the area under the curve shows the current urban damage. The urban damage estimation is a prediction if flood protection is employed, and Table 2 is a summary of the results outlined in Fig. 4.

Based on different scenarios, the urban damage in Zimbabwe for 2030 is outlined in Fig. 4. According to scenario A, B, and C, the annual

Table 1
The employed scenarios.

	Name	Description and explanation
Scenario A	SSP2	Assumes a continuation of the socioeconomic development
	$RCP_{4.5}$	A moderate climate change is assumed
Scenario B	SSP2	Assumes a continuation of the socioeconomic development
	$RCP_{8.5}$	A severe climate change is assumed
Scenario C	SSP3	Fragmented economies and uncontrolled population growth is assumed
	$RCP_{8.5}$	A severe climate change is assumed

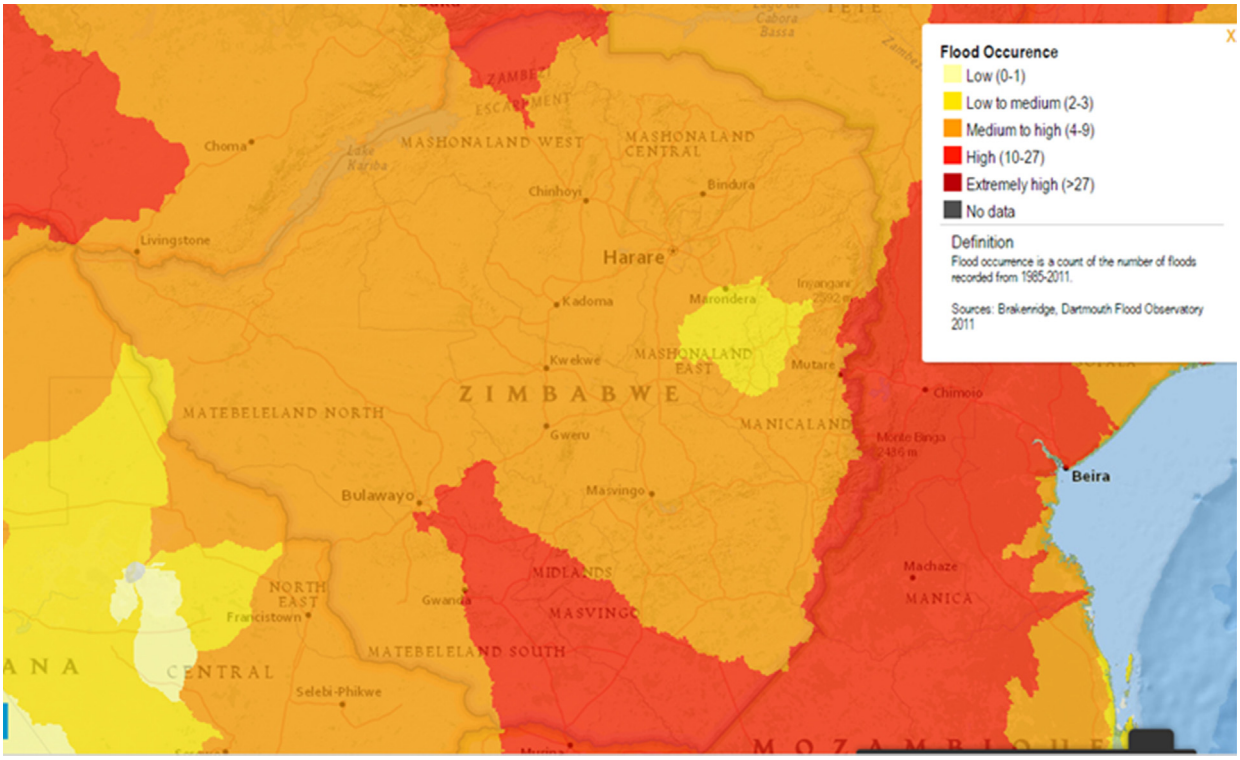

Fig. 1. Flood risk map of Zimbabwe [3].

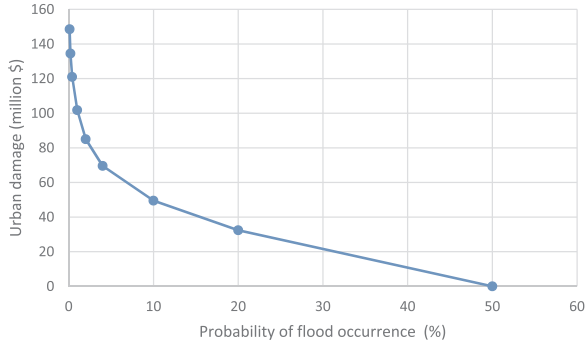

Fig. 2. Urban damage based on 5-year flood protection level.

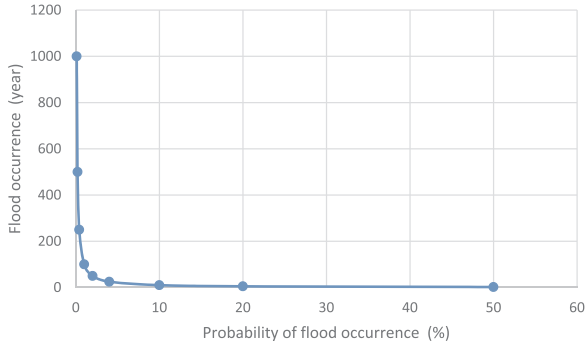

Fig. 3. Flood occurrence based on 5-year flood protection level.

current expected urban damage for Zimbabwe is $11.4 million accounting for its existing country-wide average 5-year flood protection. By 2030, according to scenario A, 66.0% of the expected increase in annual urban damage in Zimbabwe could be driven by socio-economic change, 34.0% could be driven by climate change and annual urban damage could reach $33.5 million in Zimbabwe, assuming that no additional flood protection is introduced.

Table 2
Urban damage based on 5-year flood protection.

Flood event	Probability (%)	Urban damage (Million US$)
1000-year	0.1	148.6
500-year	0.2	134.5
250-year	0.4	121.0
100-year	1	101.8
50-year	2	85.0
25	4	69.6
10	10	49.5
5	20	32.4
2	50	0.0

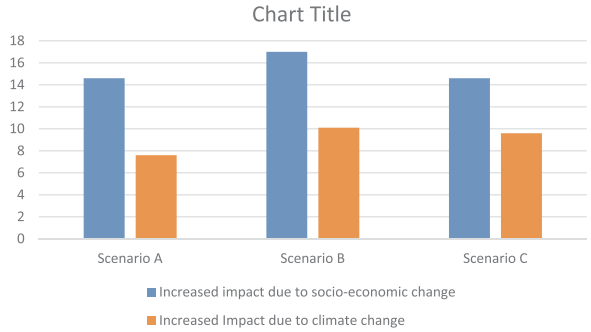

Fig. 4. Urban damage ($ million)in Zimbabwe for 2030 based on the three scenarios without flood protection.

Based on scenario B, by 2030, 62.6% of the expected increase in annual urban damage in Zimbabwe could be driven by socio-economic change, 37.4% of the expected increase in annual expected urban damage could be due to climate change and the annual urban damage could reach $38.4 million in Zimbabwe if no flood protection is introduced.

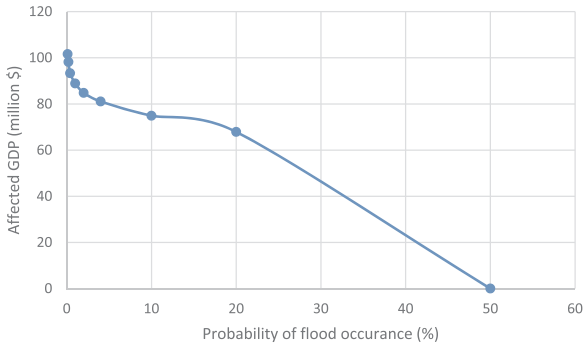

Fig. 5. Affected GDP based on a 5-year flood protection level.

Scenario C assumes that by 2030, 60.3% of the expected increase in annual urban damage in Zimbabwe could be driven by socio-economic change assuming that no additional flood protection is introduced. Again with the assumption of no introduction of any flood protection, by 2030, 39.7% of the expected increase in annual expected urban damage in Zimbabwe could be driven by climate change and the annual urban damage could reach $35.6 million.

5.2. Affected Gross Domestic Product

The Gross Domestic Product (GDP) that is affected by inland flooding in a given area annually is estimated. The Analyzer overlays a global inundation map on a global GDP map to reveal the dollar value of assets regularly exposed to inland floods [2]. Based on a 5-year flood protection level in Zimbabwe, Fig. 5 reveals the affected GDP and Table 3 summarizes the obtained results. The estimated Affected GDP will be a possible outcome if there is no flood protection employed.

In Fig. 6, scenarios A, B and C assume that the current annual expected affected GDP for Zimbabwe is $15.3 million accounting for its existing country-wide average 5-year flood protection. Assuming that no flood protection is introduced, scenario A predicts that by 2030, 62.4% of the expected increase in annual affected GDP in Zimbabwe could be driven by socio-economic change,37.6% by climate change and the annual affected GDP could reach $29.4 million.

Scenario B projects that by 2030, 36.8% of the expected increase in annual expected affected GDP in Zimbabwe could be driven by climate change, 63.2% by socio-economic change and the annual affected GDP could reach $28.4 million, by assuming that no additional flood protection is introduced.

By 2030, based on scenario C, 37.4% of the expected increase in annual expected affected GDP in Zimbabwe could be driven by climate change, whilst 65.3% could be driven by socio-economic change and the annual affected GDP could reach $31.2 million. This is by assuming that no additional flood protection is introduced.

Table 3
Affected GDP based on 5-year flood protection.

Flood event	Probability (%)	Affected GDP (Million $)
1000-year	0.1	101.6
500-year	0.2	98.2
250-year	0.4	93.3
100-year	1	88.9
50-year	2	84.8
25	4	81.1
10	10	74.9
5	20	67.9
2	50	0.0

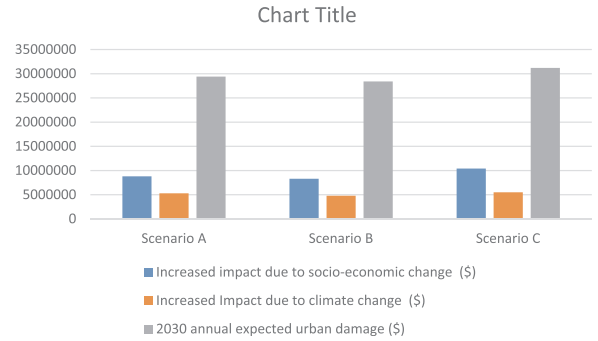

Fig. 6. Affected GDP in Zimbabwe for 2030 based on the three scenarios without flood protection.

5.3. Affected Population

The Affected Population is an estimation of the number of people affected by inland flooding annually in a given area. The Analyzer overlays a global inundation map on a global population map to reveal the total population exposed to inland floods [2]. Based on a 5-year flood protection level in Zimbabwe, Fig. 7 shows the affected Population. Table 4 summarizes the results obtained from the points marked on the graph in Fig. 7. The estimated Affected Population will be a possible outcome if there is no flood protection.

In Fig. 8, the current annual expected affected population for Zimbabwe is 24.4 thousand, based on scenarios A, B and C, accounting for its existing country-wide average 5-year flood protection. According to scenario A, assuming that no flood protection level is employed, by 2030, the annual affected population could reach 2.2 thousand with 100% of the expected increase in the annual expected affected population being driven by socio-economic change and 0% by climate change.

Results from scenario B shows that there is no increase in population expected to be driven by climate change thus by 2030, 100% of the expected increase in annual expected affected population in Zimbabwe could be driven by socio-economic change. The annual affected population is projected reach 24.0 thousand in Zimbabwe, by 2030, assuming that no additional flood protection is employed.

Scenario C predicts that in Zimbabwe by 2030, the annual affected population could reach 30.5 thousand with 50.5% of the expected increase in the annual affected population being driven by socio-economic change and the remaining 49.5% being driven by climate change, assuming no introduction of any flood protection level.

6. Discussions

The obtained results from Aqueduct Flood Analyzer software outlined the possible monetary value of the of the losses that could be incurred due to flooding, with and without employing any flood

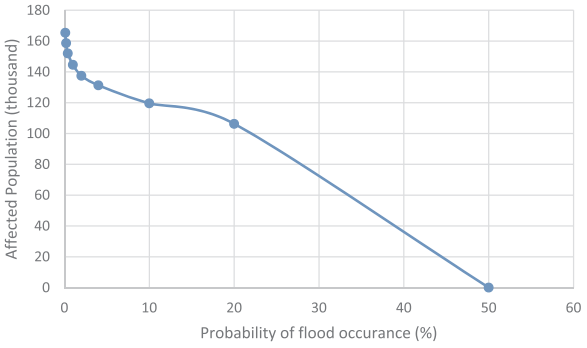

Fig. 7. Affected population based on a 5-year flood protection level.

Table 4
Affected Population based on 5-year flood protection.

Flood event	Probability (%)	Affected Population (Thousand)
1000-year	0.1	165.4
500-year	0.2	158.7
250-year	0.4	152.0
100-year	1	144.6
50-year	2	137.5
25	4	131.3
10	10	119.6
5	20	106.3
2	50	0.0

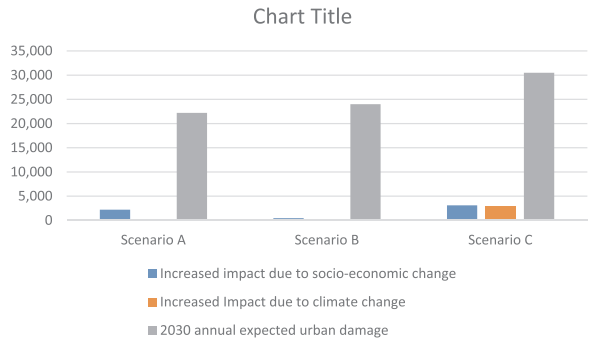

Fig. 8. Affected population in Zimbabwe for 2030 based on different scenarios without flood protection.

protection level. Three different scenarios where employed and projections were done up to the year 2030. Further analysis of the Scenario C results, outline that by introducing a flood 5-year flood protection level, annual urban damaged could be saved by $35.6 million, whilst affected GDP could be reduced by $31.2 million and a reduction of 30.5 thousand in affected population is predicted. The results of this present study are highly influenced by population growth and of course climate change which results in extreme weather conditions. The presented flood protection levels can be employed as a sustainable flood mitigation measure.

Some of the flood management and mitigation strategies currently being employed in Zimbabwe have failed due to either lack of execution of duties on time by the respective organizations or due to the unsustainability of these measures. Against this backdrop, it is therefore of paramount importance to suggest sustainable solutions that will help reduce the social, environmental and economic damages caused by floods. Sustainability in this context is being defined as the capability of the suggested measures to be long-lasting, causing less or no damage to the environment at the same time preventing the exhaustion of the natural resources. The following are some recommended sustainable flood mitigation measures that could be utilized in Zimbabwe integrated with the flood protection level proposed in this present study;

- Increasing flood awareness programs in all schools and other relevant institutions.
- Payment of flood insurance to the those residing in the flood-prone areas.
- Construction of flood resistant and elevated infrastructures.
- Establishment of automatic flood warning systems that are easily accessed and comprehended by all stakeholders [20,27].

- Construction of new sustainable drainage pathways and water harvesting structures.
- Construction of green roofs to reduce run-off water.
- Modelling and quantitative analysis of flooding using resilience simulator [35]
- afforestation, reforestation and restoration of floodplain forests.
- River reconnection with the adjoining floodplain can be used for water storage which is less expensive than the artificial constructions.
- Development of community capital through flood action groups [22].

Integration of the above-suggested measures to the ones being currently employed in Zimbabwe would not only reduce the damages incurred due to flood events but also help restore a clean and healthy environment.

7. Conclusion

As flood events continue to prevail due to climate change, it is possible to reduce their future effects by learning from past experiences as well as employing flood protection levels and flood forecasting. Complete elimination of flooding as a disaster is impossible but proper management and mitigation measures can be enforced to reduce social, environmental and economic losses due to flooding. In this research, a flood analysis in Zimbabwe was assessed utilizing AQUEDUCT Global Flood Analyzer for the impact analysis, which is based on the GDP, population and the present and future, urban damage up to 2030. Proposed analysis approach can help to reduce the loss of lives, national GDP and environmental loss. The recommended measures would, therefore, reduce the rate of environmental degradation and help better restoring a cleaner and healthier environment for a sustainable future.

To effectively estimate future changes, three scenarios obtained from the Intergovernmental Panel on Climate Change 5th Assessment Report were utilized. For the generation of mean monthly precipitation from 2011 to 2100, 1981–2010 data was input into the Meteonorm V7 software. A 5-year flood protection was proposed, and the urban damage due to the flood events, the population at risk and the effects of this disaster on GDP was determined. This study outlined that in any given year, the majority of Zimbabwe has a low to a medium that is 2–3% probability of flood occurrence in which a 5-year flood has a 20% occurrence probability in any given year. If there is no flood protection employed, this 5-year flood could cause 106.3 thousand affected population, $32.4 million urban damage and $67.9 million affected GDP. Given the limitations described above, the results are meant to provide an indication of the magnitude of the risk and an expected risk magnitude change in the future. The results obtained together with the other proposed sustainable mitigation measures in this study can also be integrated into the disaster management and mitigation portfolio and policies of Zimbabwe to help reduce the future effects of flooding in the country. For future studies, real data from the meteorological department of Zimbabwe could be obtained to increase the accuracy of the study, instead of utilizing the Meteornorm V7 software. Furthermore, visiting the communities that are most vulnerable to flood events to analyze more on how best they can be helped ensures a tailor-made approach which will be more efficient as it addresses the exact needs and solutions to a manageable group or community. A similar approach can be more efficient as argued by [24], as they assessed the coping capacities and vulnerability of Zimbabwean rural women to drought events.

References

[1] K. Abhas, J.L. Jha, Robin Bloch Cities and flooding. A Guide Integr. Urban floodrisk Manag. 21st Century [Internet]. 2011. Available from.
[2] Analyzer AGF. Floods.wri.org [Internet], 2016. Available from.
[3] Aqueduct Water Risk Atlas (a) [Internet], 2016. Available from: 〈http://www.wri.org/applications/maps/aqueduct-atlas/#x=28.18&y=-21.93&s=ws!20!28!c&t=waterrisk&w=def&g=0&i=BWS-16!WSV-4!SV-2!HFO-4!DRO-4!STOR-8!GW-8!WRI-4!ECOS-2!MC-4!WCG-8!ECOV-2!&tr=ind-1!prj-1&l=6&b=terrain&m=single-HFO〉.
[4] S. Asumadu-Sarkodie, P.O.P. Rufangura, Impact analysis of flood in Accra, Ghana Adv. Appl. Sci. Res. (2015).
[5] S. Asumadu-Sarkodie, P. Rufangura, H.O.P. Jayaweera, Situational analysis of flood

and drought in Rwanda, Int. J. Sci. Eng. Res. 6 (2015).
[6] C. Raleigh, H.J. Choi, DK, The devil is in the details: an investigation of the relationships between conflict, food price and climate across Africa, Glob. Environ. Change 32 (2015) 187–199.
[7] C. Raleigh, H.J. Choi, DK, The devil is in the details: an investigation of the relationships between conflict, food price and climate across Africa, Glob. Environ. Change 32 (2015) 187–199.
[8] Chipo Mudavanhu, The impact of flood disasters on child education in Muzarabani District, Zimbabwe, J. Disaster Risk Stud. 6 (2014) 1–8 〈https://journals.co.za/content/jemba/6/1/EJC163444〉.
[9] D. Dodman, M. Rusca, S. Colenbrander, African Urbanisation and Urbanism: implications for risk accumulation and reduction, Int. J. Disaster Risk Reduct. 26 (2017) 7–15, https://doi.org/10.1016/J.IJDRR.2017.06.029.
[10] E. Mavhura, S.B. Manyena, A.E. Collins, D. Manatsa, Indigenous knowledge, coping strategies and resilience to floods in Muzarabani, Zimbabwe, Int. J. Disaster Risk Reduct. 5 (2013) 38–48, https://doi.org/10.1016/J.IJDRR.2013.07.001.
[11] D. Eilander, H. Winsemius, P. Ward, A.D.H.A. Loaiza, M. Luo, T. Verlaan, Global coastal flood hazard mapping, in: EGU General Assembly 2017, 2017.
[12] Mavhura Emmanuel, Andrew Collins, Pathias Paradzayi Bongo, Flood vulnerability and relocation readiness in Zimbabwe, Disaster Prev. Manag. Int. J. 26 (2017) 41–54 〈https://www.emeraldinsight.com/doi/pdfplus/10.1108/DPM-05-2016-0101 〉.
[13] F. Gassert, M. Luck, M. Landis, P. Reig, TS. Aqueduct Global Maps 2.1: Constructing Decision-Relevant Global Water Risk Indicators [Internet], 2014. Available from: 〈http://www.wri.org/publication/aqueductglobalmaps-21-indicators〉.
[14] Farai Mutsaka, Nearly 250 people have died from flooding in Zimbabwe, months after severe drought, 2017. 〈https://globalnews.ca/news/3285461/zimbabwe-flooding-kills-250/〉.
[15] C. Iceland, The Aqueduct Global Flood Analyzer, in: EGU General Assembly 2017, 2017.
[16] IEE. Earthzine.org: IEEE Publication Fostering Earth Observation and Global Awareness. [Internet], 2013. Available from: 〈https://earthzine.org/〉.
[17] L.P. Li, K.M. Zhang, F.X. LuoT, An analysis of the drought and flood hazard characteristics and risks during the pre-rainy season in South China, Nat. Hazards (2013).
[18] M. Luck, M.G.F. Landis, Aqueduct Water Stress Projections: Decadal Projections of Water Supply and Demand Using CMIP5 GCMs, 2015.
[19] F. Luino, L. Turconi, G. Paliaga, F. Faccini, F. Marincioni, Torrential floods in the upper Soana Valley (NW Italian Alps): geomorphological processes and risk-reduction strategies, Int. J. Disaster Risk Reduct. 27 (2018) 343–354, https://doi.org/10.1016/J.IJDRR.2017.10.021.
[20] D. Lumbroso, How can policymakers in sub-Saharan Africa make early warning systems more effective? The case of Uganda, Int. J. Disaster Risk Reduct. 27 (2018) 530–540, https://doi.org/10.1016/J.IJDRR.2017.11.017.
[21] C. Mannaerts, Watershed Hydrological Methods, Enschede, The Netherlands, 1996.
[22] L. McEwen, A. Holmes, N. Quinn, P. Cobbing, "Learning for resilience": developing community capital through flood action groups in urban flood risk settings with lower social capital, Int. J. Disaster Risk Reduct. 27 (2018) 329–342, https://doi.org/10.1016/J.IJDRR.2017.10.018.
[23] Meteotest. Meteonorm Software [Internet], 2017. Available from: 〈http://www.meteonorm.com/〉.
[24] A. Ncube, P.T. Mangwaya, A.A. Ogundeji, Assessing vulnerability and coping capacities of rural women to drought: a case study of Zvishavane district, Zimbabwe, Int. J. Disaster Risk Reduct. 28 (2018) 69–79, https://doi.org/10.1016/J.IJDRR.2018.02.023.
[25] E. Osuteye, C. Johnson, D. Brown, The data gap: an analysis of data availability on disaster losses in sub-Saharan African cities, Int. J. Disaster Risk Reduct. 26 (2017) 24–33, https://doi.org/10.1016/J.IJDRR.2017.09.026.
[26] Oxford, English Oxford Living Dictionaries, 2018. 〈https://en.oxforddictionaries.com/definition/flood〉.
[27] C. Rossi, F.S. Acerbo, K. Ylinen, I. Juga, P. Nurmi, A. Bosca, F. Tarasconi, M. Cristoforetti, A. Alikadic, Early detection and information extraction for weather-induced floods using social media streams, Int. J. Disaster Risk Reduct. (2018), https://doi.org/10.1016/j.ijdrr.2018.03.002.
[28] S. Rufat, E. Tate, C.G. Burton, A.S. Maroof, Social vulnerability to floods: review of case studies and implications for measurement, Int. J. Disaster Risk Reduct. 14 (2015) 470–486, https://doi.org/10.1016/J.IJDRR.2015.09.013.
[29] D. Satterthwaite, The impact of urban development on risk in sub-Saharan Africa's cities with a focus on small and intermediate urban centres, Int. J. Disaster Risk Reduct. 26 (2017) 16–23, https://doi.org/10.1016/J.IJDRR.2017.09.025.
[30] C.M. Shreve, I. Kelman, Does mitigation save? Reviewing cost-benefit analyses of disaster risk reduction, Int. J. Disaster Risk Reduct. 10 (2014) 213–235, https://doi.org/10.1016/J.IJDRR.2014.08.004.
[31] E. Sutanudjaja, R. van Beek, H. Winsemius, P.B.M. Ward New version of 1 km global river flood hazard maps for the next generation of Aqueduct Global Flood Analyzer, in: EGU General Assembly, 2017.
[32] W. Viessman Jr., G. Lewis, Introduction to Hydrology, Happer Collins College Publishers, New York, 1996.
[33] P.J. Ward, M. Kummu, U. Lall, Flood frequencies and durations and their response to El Niño Southern Oscillation: global analysis, J. Hydrol. (2016).
[34] H.C. Winsemius, C.J. Jeroen, H. Aerts, P. Ludovicus, H. van Beek, F. Marc, P. Bierkens, A. Bouwman, B. Jongman, C. Jaap, J. Kwadijk, W.L.P.L. Ligtvoet, P.J. Ward, V.D.P. van, Global drivers of future river flood risk, Nat. Clim. Chang. [Internet] (2015) (Available from 〈https://www.researchgate.net/publication/287792582 〉).
[35] N. Zare, N. Talebbeydokhti, Policies and governance impact maps of floods on metropolitan Shiraz (the first step toward resilience modeling of the city), Int. J. Disaster Risk Reduct. (2018), https://doi.org/10.1016/j.ijdrr.2018.03.003.